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- (54) **INTEGRATED HOSTED DIRECTORY**
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See application file for complete search history.

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(Continued)

- (56) **References Cited**
U.S. PATENT DOCUMENTS

5,944,824 A * 8/1999 He H04L 63/102
726/6
6,182,131 B1 * 1/2001 Dean H04L 67/306
709/222

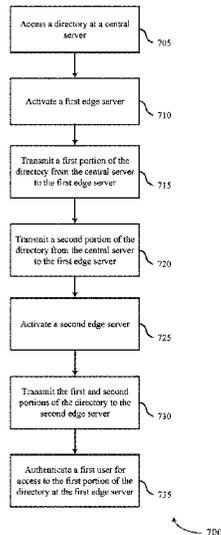
(Continued)

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- (57) **ABSTRACT**
Methods, systems, and devices for enterprise-wide management of disparate devices, applications, and users are described. A cloud-based central server may maintain an integrated hosted directory, which may allow user authentication, authorization, and management of information technology (IT) resources across device types, operating systems, and software-as-a-service (SaaS) and on-premises applications. IT resources for multiple and separate customers may be managed from a single, central directory, and servers may be brought online to allow access to the directory according to system loading.

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G06F 21/45 (2013.01)
G06Q 10/10 (2023.01)
H04L 61/4523 (2022.01)

17 Claims, 10 Drawing Sheets



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(56)

References Cited

U.S. PATENT DOCUMENTS

6,243,816 B1 * 6/2001 Fang H04L 63/0815
707/999.009
6,553,413 B1 * 4/2003 Leighton H04L 67/289
709/200
6,880,156 B1 * 4/2005 Landherr G06F 9/5083
709/229
7,181,523 B2 * 2/2007 Sim G06F 16/182
709/224
7,783,777 B1 * 8/2010 Pabla G06F 16/1834
709/239
8,438,254 B2 * 5/2013 Hopen H04L 67/1034
709/224
8,682,916 B2 * 3/2014 Wong H04L 67/06
707/758
10,382,445 B1 * 8/2019 Mantel G06Q 20/3223
2002/0010798 A1 * 1/2002 Ben-Shaul H04L 67/52
707/E17.116
2002/0055989 A1 * 5/2002 Stringer-Calvert
H04L 12/4679
709/250
2002/0069420 A1 * 6/2002 Russell H04L 63/0428
725/92
2002/0091801 A1 * 7/2002 Lewin H04L 65/613
709/219
2002/0111845 A1 * 8/2002 Chong G06Q 10/06311
705/7.13
2002/0147610 A1 * 10/2002 Tabe G06Q 10/06
701/32.6
2002/0152318 A1 * 10/2002 Menon H04N 21/44204
709/231
2003/0229783 A1 * 12/2003 Hardt H04L 63/102
713/155
2004/0093419 A1 * 5/2004 Wehl H04L 63/06
709/214
2005/0108546 A1 * 5/2005 Lehew H04L 63/06
713/182

2007/0088797 A1 * 4/2007 Boone G06Q 10/10
709/217
2007/0254631 A1 * 11/2007 Spooner H04L 63/126
455/411
2007/0280211 A1 * 12/2007 Malueg H04L 65/1026
370/356
2009/0010426 A1 * 1/2009 Redmond H04N 21/812
348/E7.06
2009/0083183 A1 * 3/2009 Rao G06Q 50/01
705/50
2009/0113253 A1 * 4/2009 Wang H04L 67/1008
709/227
2010/0235432 A1 * 9/2010 Trojer H04L 67/104
707/827
2011/0225417 A1 * 9/2011 Maharajh H04L 65/752
713/150
2012/0198070 A1 * 8/2012 Black H04L 67/06
709/226
2013/0133043 A1 * 5/2013 Barkie H04L 63/0485
726/4
2014/0108474 A1 * 4/2014 David H04L 67/568
707/827
2014/0136712 A1 * 5/2014 Kim H04L 47/70
709/226
2014/0173694 A1 * 6/2014 Kranz H04L 63/10
726/4
2014/0289791 A1 * 9/2014 Acharya H04L 63/0236
726/1
2015/0180992 A1 * 6/2015 Thibeault H04L 67/53
709/201
2015/0271301 A1 * 9/2015 Mahoney H04L 67/1001
726/3
2015/0286816 A1 * 10/2015 Adler H04L 63/083
726/6
2015/0378769 A1 * 12/2015 Buck G06F 9/45533
718/1
2016/0253186 A1 * 9/2016 Brown H04L 67/1097
710/104
2016/0275097 A1 * 9/2016 Bain G06F 16/24575
2017/0012965 A1 * 1/2017 Hurst H04L 63/0892
2017/0339156 A1 * 11/2017 Gupta H04L 63/083
2021/0264018 A1 * 8/2021 Helles G06F 21/45
2021/0391982 A1 * 12/2021 Gagliardoni H04L 9/3239

* cited by examiner

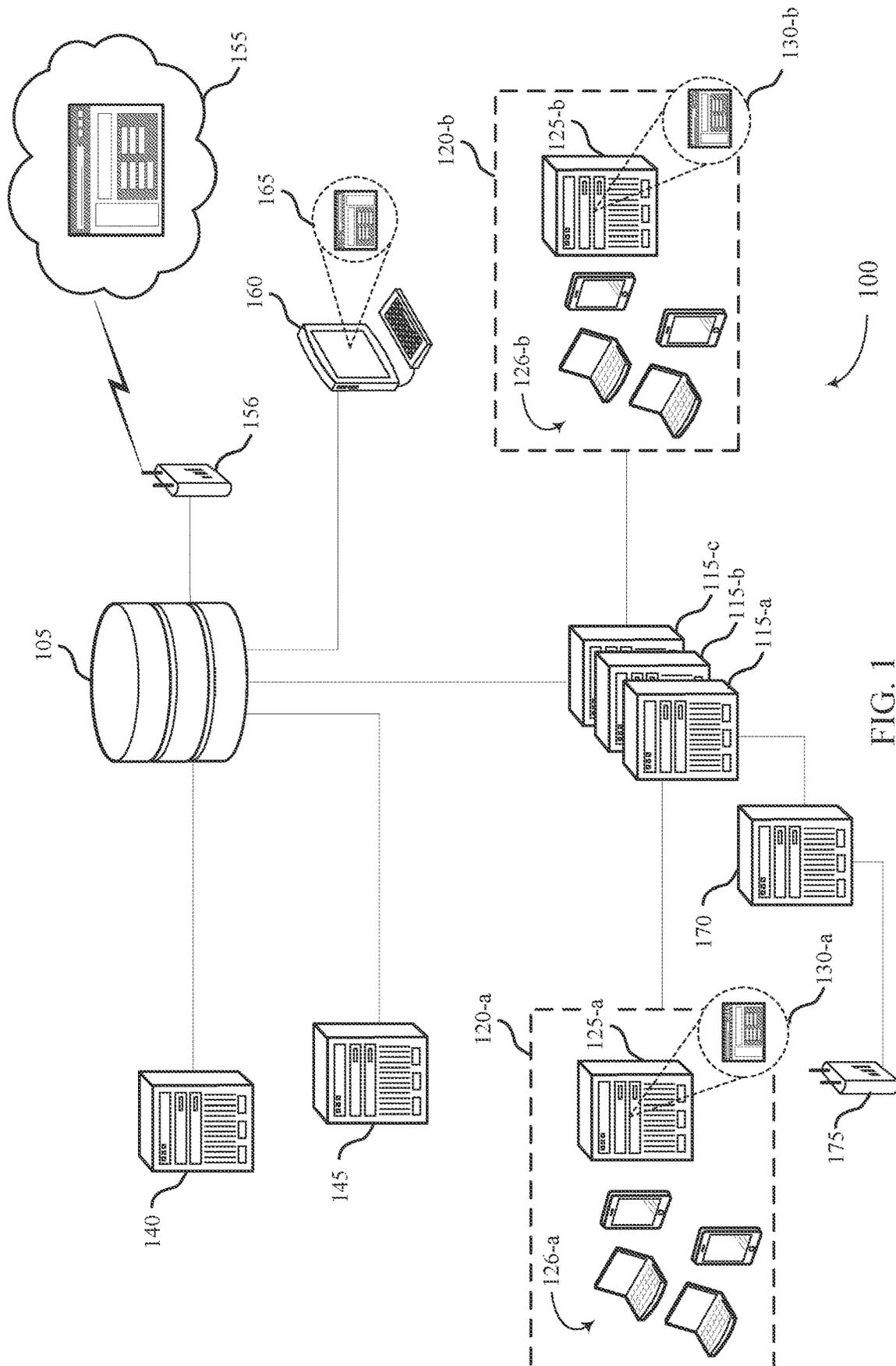


FIG. 1

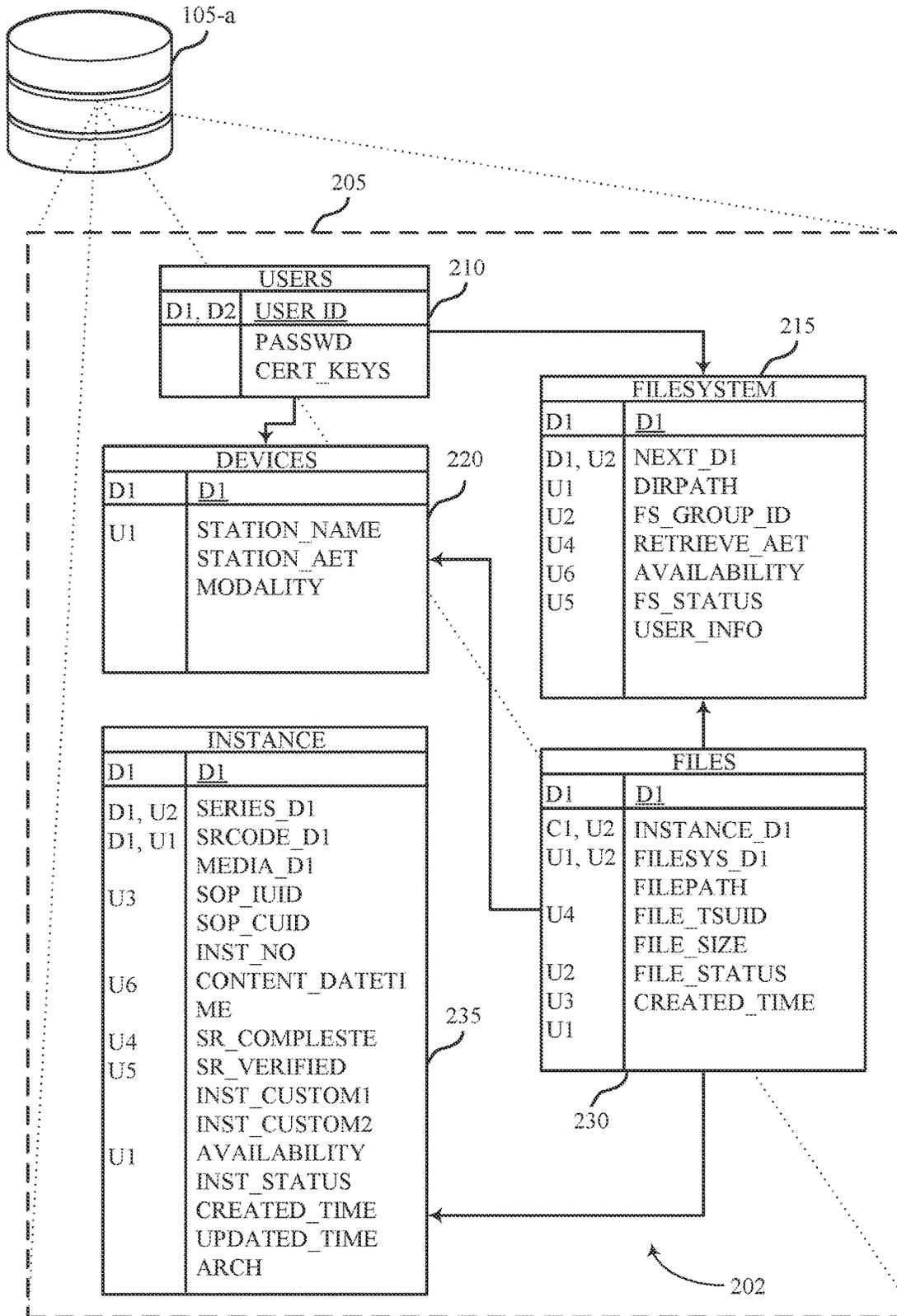


FIG. 2

200

310

- Users
- Systems**
- Tags
- Identify
- Applications
- Commands
- Settings
- Support

315

Systems

All Systems: No systems selected Hide Inactive Systems

+ Add System

Active	Name	Instance	OS	Version	Arch	Primary Adapter IP	Last Contact	Details
<input type="checkbox"/>	Windows 2008		Windows	Server 2008 R2 Datacenter	64-bit	00.00.00.0000.00	a few seconds ago	<input type="button" value="Details"/>
<input type="checkbox"/>	Linux CentOS	000000000000001001	CentOS	6	X86_64	00.00.10.00.00	a few seconds ago	<input type="button" value="Details"/>
<input type="checkbox"/>	JohnDoe-PC		Windows	7 Home Premium	64-bit		a month ago	<input type="button" value="Details"/>
<input type="checkbox"/>	windows2008		Windows	Sever 2008 R2 Datacenter	64-bit	00.00.00.0000.11	10 days ago	<input type="button" value="Details"/>
<input type="checkbox"/>	DOEVM		Ubuntu	14.04.1	i686	00.00.00.01.00	6 months ago	<input type="button" value="Details"/>
<input type="checkbox"/>	johndoe		Ubuntu	14.04	i686	00.00.00.11.00	4 months ago	<input type="button" value="Details"/>
<input type="checkbox"/>	John-Virtual		Ubuntu	14.04	i686	00.00.00.00.10	7 months ago	<input type="button" value="Details"/>

305

155-a

300

FIG. 3

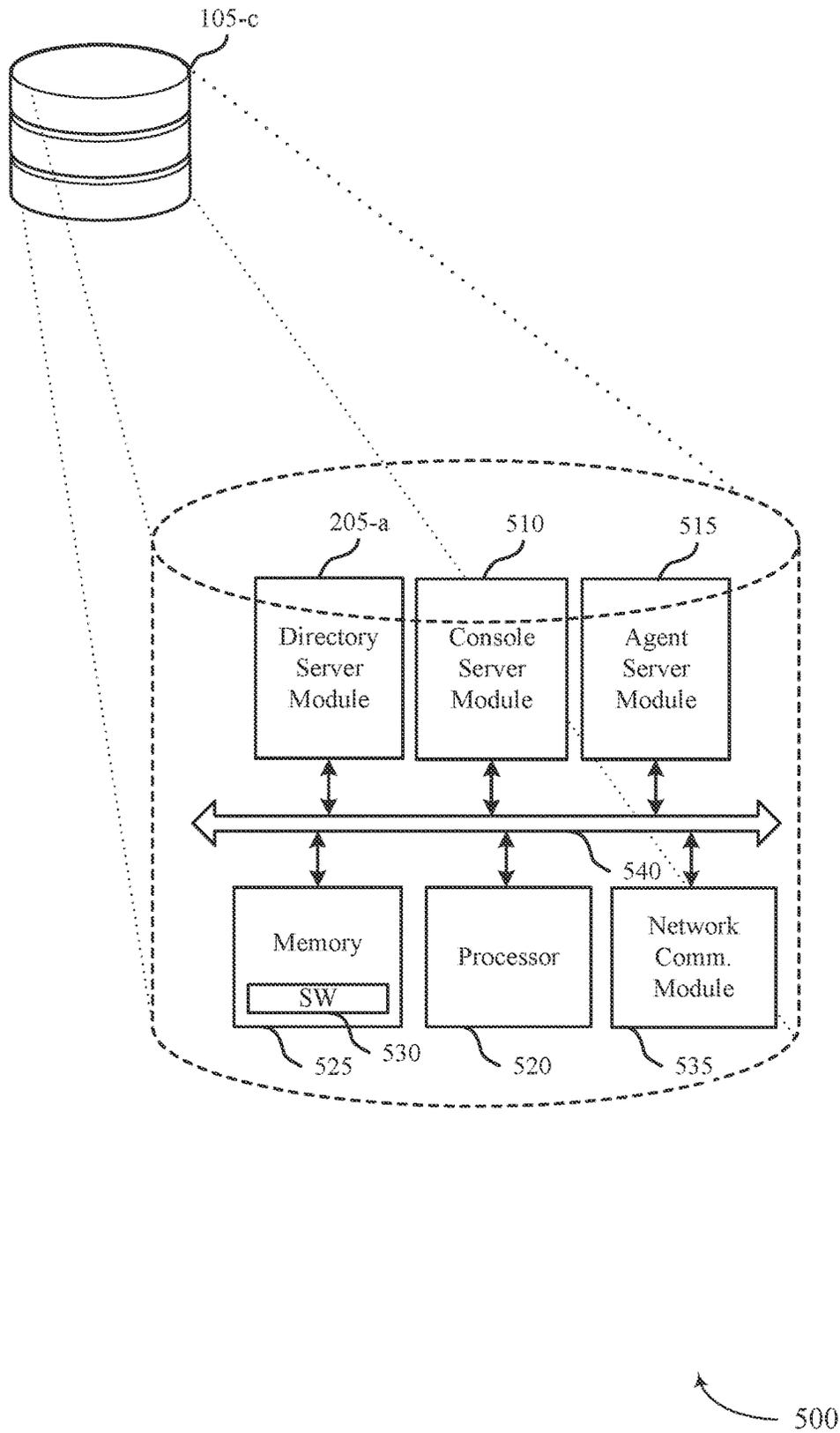


FIG. 5

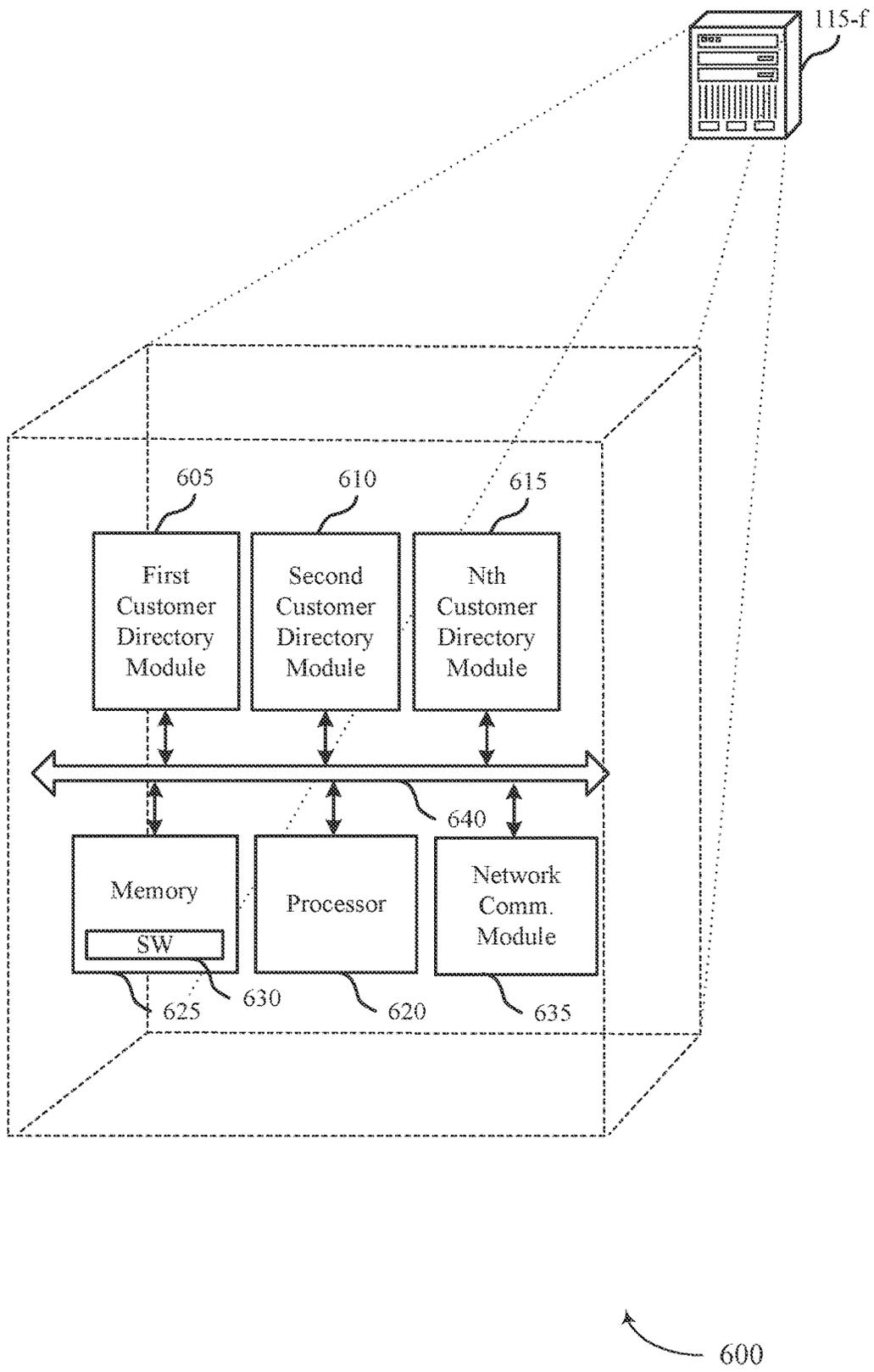


FIG. 6

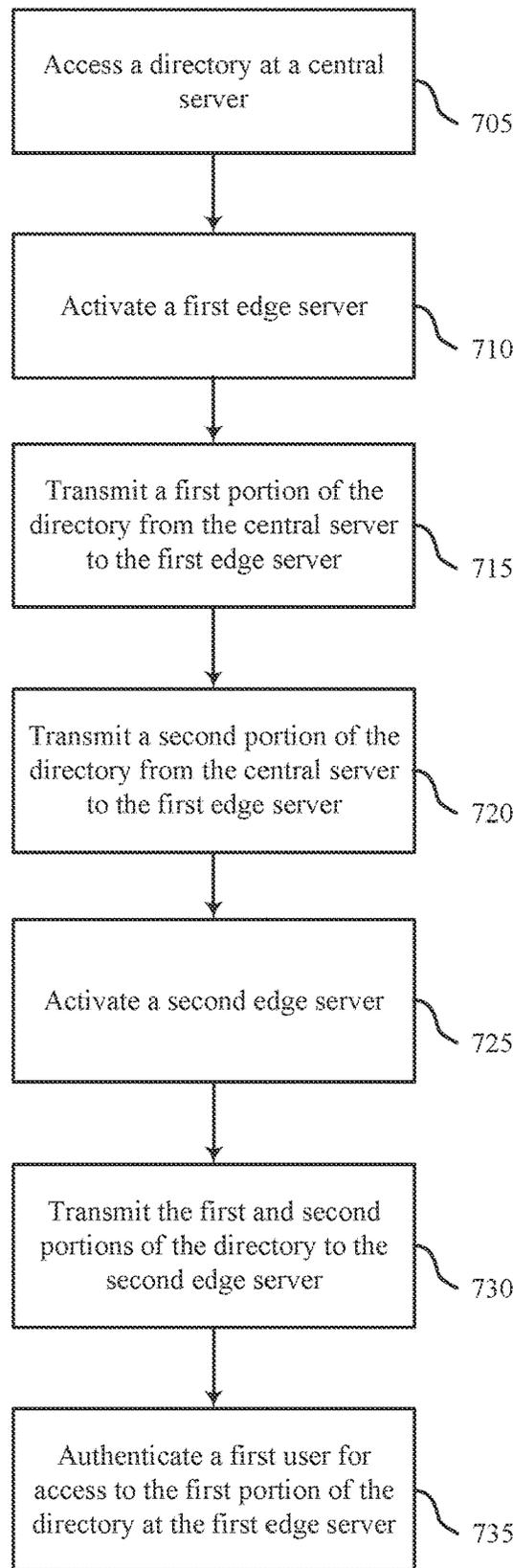


FIG. 7

700

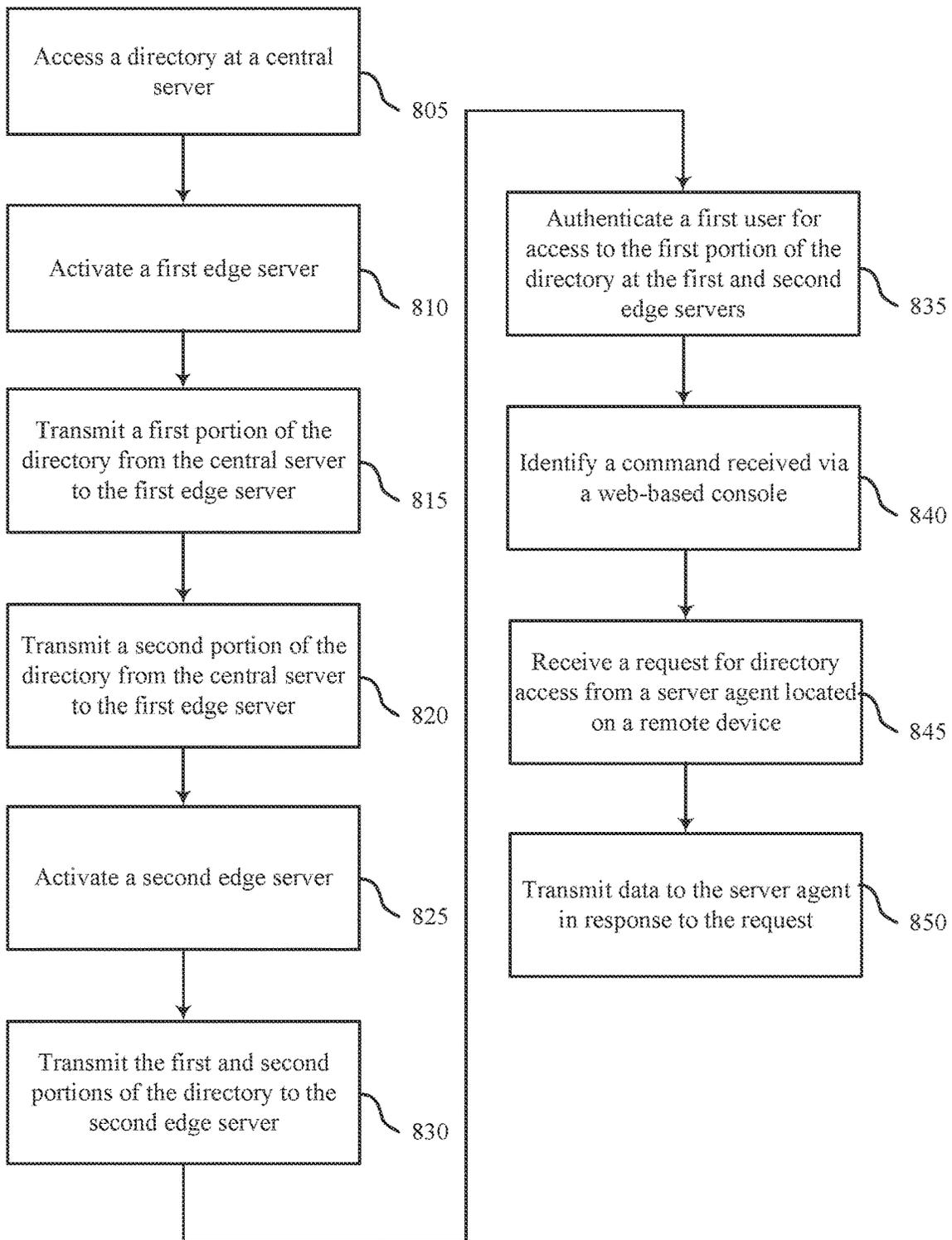


FIG. 8

800

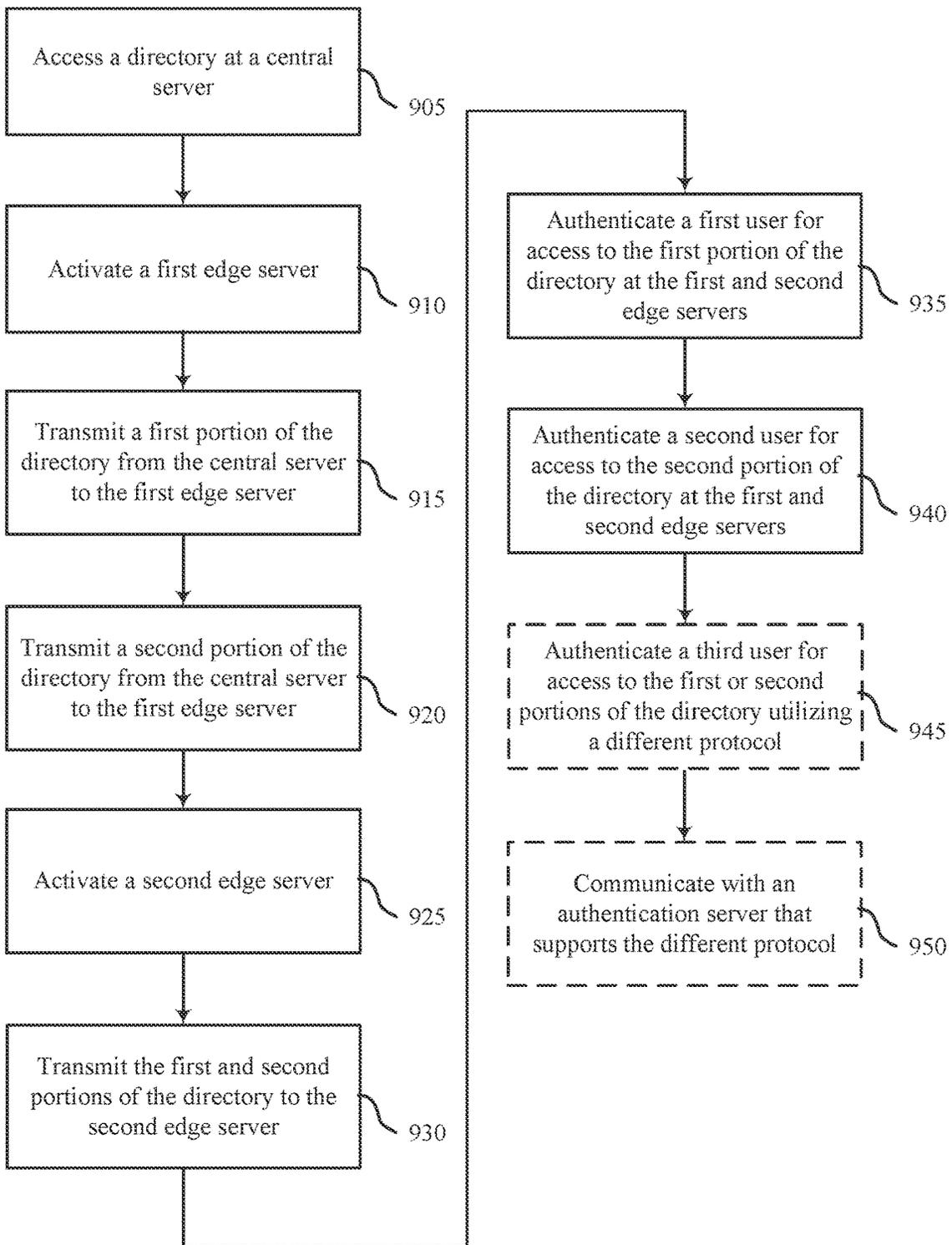


FIG. 9

900

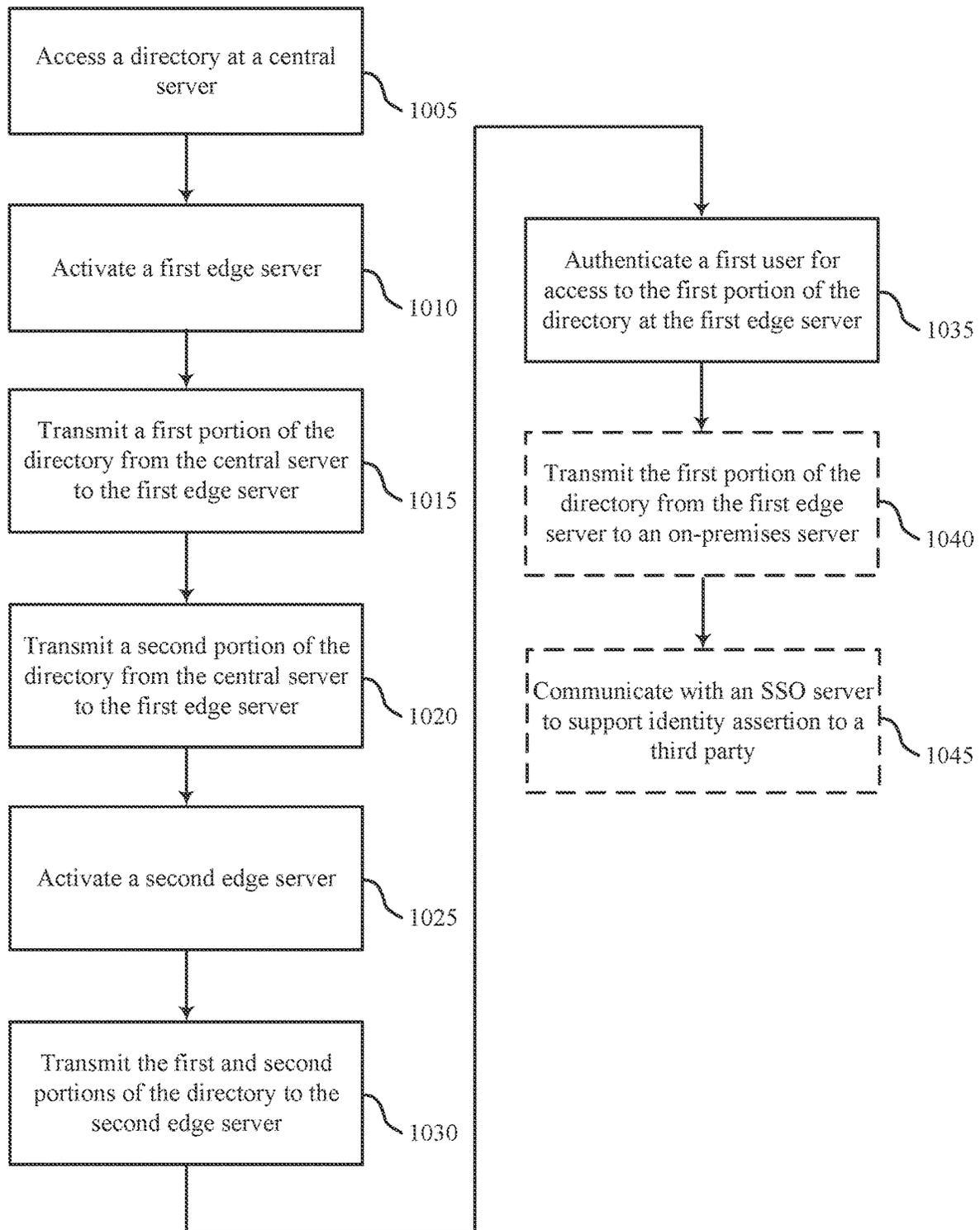


FIG. 10

1000

INTEGRATED HOSTED DIRECTORY

CROSS REFERENCES

The present application for patent is a continuation of U.S. patent application Ser. No. 16/826,666, by Bhargava et al., entitled "INTEGRATED HOSTED DIRECTORY", filed Mar. 23, 2020, which is a continuation of U.S. patent application Ser. No. 16/109,461, by Bhargava et al., entitled "INTEGRATED HOSTED DIRECTORY", filed Aug. 22, 2018, which is a continuation-in-part of U.S. patent application Ser. No. 16/043,786 by Bhargava et al., entitled "INTEGRATED HOSTED DIRECTORY", filed Jul. 24, 2018, which is a continuation of U.S. patent application Ser. No. 15/482,522 by Bhargava et al., entitled "INTEGRATED HOSTED DIRECTORY", filed Apr. 7, 2017, which is a continuation of U.S. patent application Ser. No. 14/728,511 by Bhargava et al., entitled "INTEGRATED HOSTED DIRECTORY", filed Jun. 2, 2015, each of which is assigned to the assignee hereof and incorporated by reference herein in its entirety.

BACKGROUND

Information technology (IT) and networking is increasingly leveraging remote servers and disparate resources. Organizations often rely on internet-based IT infrastructures to serve employees and clients who may be located around the globe. A single enterprise may utilize devices (including laptops, desktops, phones, tablets, printers, etc.) located on premise, within remote data centers, and hosted at remote, third-party owned servers ("the cloud"). Consequently, managing IT infrastructure has become time consuming, labor intensive, and tedious. Additionally, many organizations are relying on a software-as-a-service (SaaS) based model for applications, content, and the like; and such this SaaS-based model does not lend itself to traditional on-premises management.

While the trend toward cloud and SaaS-based infrastructure has been effective on many fronts, it has introduced a number of challenges related to system administration and user authentication. The disparate nature of servers, devices, applications, and users has given rise to increased networking complexity, security concerns, and poor interoperability of resources. A central means of managing cloud and SaaS resources, and authenticating users for those resources may thus increase the efficiency and productivity of cloud-based IT infrastructure.

SUMMARY

Methods, systems, and devices that support a central directory for enterprise-wide management of disparate devices, applications, and users are described. Within a networked, cloud-based computing system, a central server may maintain an integrated hosted directory, which may allow user authentication, authorization, and management of IT resources across devices types, operating systems, and SaaS and on-premises applications. Portions of the directory may be shared with or mirrored on various cloud-based and on-premises devices to increase access and usability by system administrators. Furthermore, IT resources for multiple separate customers may be managed from a single, central directory, and servers may be brought online to allow access to the directory according to system loading.

A method of multitenant directory management is described. The method may include: accessing a directory at

a central server, and the directory comprises IT resources for a plurality of customers; activating a first edge server of a plurality of edge servers; transmitting a first portion of the directory from the central server to the first edge server, and the first portion of the directory may include IT resources for a first customer of the plurality of customers; transmitting a second portion of the directory from the central server to the first edge server, and the second portion of the directory may include IT resources for a second customer of the plurality of customers; activating a second edge server of the plurality of edge servers based at least in part on a system load from the plurality of customers; transmitting the first and second portions of the directory to the second edge server; and authenticating a first user for access to the first portion of the directory at the first and second edge servers utilizing a first protocol.

A system for multitenant directory management is also described. The system may include a central server, which may include a directory or IT resources for a plurality of customers, a directory server that supports access to the directory using a first protocol, a console server in communication with the directory server, where the console server may provide a user interface for web-based access to the directory, and an agent server in electronic communication with the directory server and the console server, where the agent server may control server agents located on remote devices and may support agent access to the directory. The system may also include: a first edge server in electronic communication with the directory server, and the first edge server may support access to the directory using the first protocol, and may host a first portion of the directory for a first customer of the plurality of customers and a second portion of the directory for a second customer of the plurality of customers; a second edge server in electronic communication with the directory server and operable to activate if a system load from the plurality of customers is greater than a first threshold and to deactivate if the system load from the plurality of customers is less than a second threshold, where the second edge server may support access to the directory using the first protocol, and the second edge server may host the first portion of the directory for the first customer or the second portion of the directory for the second customer, or both; and an authentication server in electronic communication with the central server, where the authentication server may authenticate users from the plurality of customers for access to the first or second portions of the directory using a second protocol that is different from the first protocol.

A central server for multitenant directory management is also described. The central server may include a processor, memory in electronic communication with the processor, and instructions stored in the memory and operable when executed by the processor to cause the central server to: access a directory of IT resources for a plurality of customers; transmit a first portion of the directory to a first edge server, where the first portion of the directory may include IT resources for a first customer of the plurality of customers; transmit a second portion of the directory to the first edge server, where the second portion of the directory may include IT resources for a second customer of the plurality of customers; transmit the first portion or second portion of the directory to a second edge server, where the second edge server may be operable to activate if a system load from the plurality of customers is greater than a first threshold and to deactivate if the system load from the plurality of customers is less than a second threshold; authenticate a first user for access to the first portion of the directory at the first or

second edge server base at least in part on a request received from the first or second edge server; and authenticate a second user for access to the second portion of the directory at the first edge server based at least in part on a request received from the first edge server.

BRIEF DESCRIPTION OF THE DRAWINGS

Aspects of the disclosure are described in reference to the following figures:

FIG. 1 illustrates an exemplary system that supports multitenant directory management in accordance with various aspects of the present disclosure;

FIG. 2 illustrates an example of an integrated hosted directory in a system that supports multitenant directory management in accordance with various aspects of the present disclosure;

FIG. 3 illustrates an example of a web-based console in a system that supports multitenant directory management in accordance with various aspects of the present disclosure;

FIG. 4 illustrates an exemplary process flow in a system that supports multitenant directory management in accordance with various aspects of the present disclosure;

FIG. 5 illustrates an example of a central server that supports multitenant directory management in accordance with various aspects of the present disclosure;

FIG. 6 illustrates an example of a device that supports multitenant directory management in accordance with various aspects of the present disclosure; and

FIGS. 7-10 illustrate methods for multitenant directory management in accordance with various aspects of the present disclosure.

DETAILED DESCRIPTION

A central directory for enterprise-wide management of disparate devices, applications, and users may allow IT system administrators to authenticate users across device types, operating systems, on-premises applications, or SaaS-based applications. For instance, users (e.g., organizational employees), devices, and applications may be populated into a central store via a web-based console. Permissions may be assigned for all IT resources (e.g., devices, applications, file systems, files, etc.) within consoles, such that once populated, the system administrator may readily manage users and IT resources from a single location. The console may also allow users to manage, through a self-service portal, certain functions—like password resets, profiles, and certificate-based keys—to IT resources to which those users have permissions. The integrated hosted directory may thus reduce management complexity.

Additionally, a single directory may host resources for several different organizations. Unlike traditional or pre-cloud directories, the integrated hosted directory described herein may provide for management of IT resources and users from different customers (e.g., enterprises). This multitenant directory management may allow for selective administration and permission granting between customers. That is, users from one customer may be granted permission to devices, applications, files, and the like, of other customers, providing a simple, seamless way of managing IT resources across organizations.

Aspects of the disclosure are initially described below in the context of a system that supports multitenant directory management. Various examples of an integrated hosted directory and web-based console are then described. These and other aspects of the disclosure are further illustrated by

and described with reference to apparatus diagrams, system diagrams, and flowcharts that relate to multitenant directory management.

FIG. 1 illustrates an exemplary system **100** that supports multitenant directory management in accordance with various aspects of the present disclosure. The system **100** includes a central server **105**. The central server **105** may include a directory—such as the integrated hosted directory described herein—that may include IT resources for several different customers. An example of the directory is described in more detail with reference to FIG. 2. As used here, the term customer may refer to an enterprise or organization, rather than an individual. An individual member or element of a customer may be referred to as a user.

The central server **105** may include a directory server, which may host a directory, and which may support access to the directory using, e.g., a particular protocol. In some examples, the directory server supports access to the directory using Lightweight Directory Access Protocol (LDAP). The central server **105** may also include a console server, which may provide a user interface for web-based access to the directory. In some examples, the central server **105** also includes an agent server that controls server agents located on remote devices and may support agent access to the directory.

In some cases, the system **100** includes a number of devices **115**, devices **115** may be located physically near a customer and physically remote from the central server **105**. Devices **115** may reflect replicated portions of the central server **105**, but their location proximate to a customer may, as compared to an exclusively centralized system, reduce latency, reduce data transmission costs, increase quality of service (QoS), and the like. Moreover, devices **115** may be scalable, such that additional devices may be activated (e.g., “spun up”) to accommodate and respond to increases in system loading.

For instance, portions of the directory housed on central server **105** may be reflected (e.g., transmitted) to device **115-a**. Users may access the directory, or portion of the directory, at device **115-a** utilizing the same protocol as they would to access the directory at the central server **105** (e.g., LDAP). If system loading, as experienced at device **115-a**, exceeds a threshold, an additional device **115-b** may be activated. For example, if a number of users attempting access exceeds a preset value or if latency reaches a particular threshold (e.g., a time delay, which may be on the order of tenths or tens of a second), device **115-b** may be spun up. By way of example, system loading may be based on central processing unit (CPU) usage of device **115-a**. If a threshold CPU usage exceeds a threshold (e.g., 80 percent of capacity), device **115-b** may be activated. In other examples, a threshold may be based on memory usage, disk input/output (**110**), a number of customer request, or the like. In such cases, the portions of the directory reflected on device **115-a** may also be reflected or transmitted to **115-b**. If system loading falls below the threshold, or some other threshold value, device **115-b** may be taken offline. Alternatively, if system loading continues to increase beyond a subsequent threshold, an additional device **115-c** may be activated, and the portions of the directory may be reflected to it.

Devices **115** may be any number of entities. For example, device **115-a** may be or implement a server, such as an edge server or a file server. In other examples, device **115-a** may be or implement a wireless device, such as a user equipment (UE) or wireless station (STA). In yet other examples, device **115-a** may be a processor which executes a software

application, which may be housed in a wired or wireless device. The software application may implement a server, such as an edge server or a file server. Furthermore, system 100 may include different varieties of device 115. For example, 115-*a* may be a file server, another device 115 may be a processor and yet another device 115 may be a UE or STA.

The system 100 may also support certain authentication, authorization, and management on the premises 120 of customers. For example, on-premises (or “on-prem”) server 125-*a*, which may be physically located on the premises 120-*a* of a first customer, may include a replica module 130-*a*. Replica module 130-*a* may host a portion of the directory with IT resources of, accessible to, or managed by the first customer. That is, a portion of the directory hosted on central server 105 may be reflected to replica module 130-*a*. This may be via an device 115, in some cases. The devices 126-*a* may thus, in some examples, be managed by and may be included in the portion of the directory hosted by replica module 130-*a*. Additionally or alternatively, the devices 126-*a* may include computing devices of various types (e.g., mobile phones, tablets, notebook computers, desktop computers, servers, etc.), which may utilize various operating systems. Replica module 130-*a* may thus provide a familiar, local version of the directory, which may be securely maintained and readily accessed by the first customer. As used herein, on-premises may refer to a server, device, or the like that is within the control of the customer. In some cases, this may include servers located in a remote data center owned or controlled by the customer, which may be contrasted with servers maintained or controlled by a third-party and accessible to the customer via the interact (e.g., cloud servers).

Additionally, on-premises server 125-*b*, which may be physically located on the premises 120-*b* of a second customer, may include a replica module 130-*b*. Replica module 130-*b* may host a portion of the directory with IT resources of, accessible to, or managed by the second customer. Similar to replica module 130-*a*, a portion of the directory hosted on central server 105 may be reflected to replica module 130-*b*. But these portions may be different (e.g., include different users, IT resources, etc.). The devices 126-*b* may be managed by and may be included in the portion of the directory hosted by replica module 130-*b*. Additionally or alternatively, the devices 126-*b* may include computing devices of various types (e.g., mobile phones, tablets, notebook computers, desktop computers, servers, etc.), which may utilize various operating systems.

In some cases, system 100 includes a single-sign-on (SSO) server 140. The SSO server 140 may provide access to, or may be represented in the directory. The SSO server 140 may facilitate assertion of a user’s identity to a third party using, for instance, an authentication protocol, such as Security Markup Language (SAML), OpenID, OAuth, or the like. Thus, users who have been authenticated at the central server 105 (or an device 115, replica module 130, etc.) may gain access to third-party applications, websites, content, or the like, without the necessity of an additional credentialing process. That is, a user authorized by the system 100 may avoid entering login credentials with certain trusted and trusting third parties. In some cases, the SSO server 140 may facilitate access to the central server 105, thus the directory hosted there, without the necessity of further user authentication. For instance, a user authenticated by a trusted third party may gain access to the central server without the necessity of further credentialing.

In some examples, system 100 includes a separate authentication server 145. The authentication server 145 may authenticate users from various customers to the central server 105. For example, a user may access the authentication server with a device, and may authenticate with the authentication server 145. This may involve the user entering a username and password. This authentication process may include the authentication server 145 exchanging a ticket or key with a device of the user. The user may then access the central server 105 or an device 115, for instance, based on the authentication with the authentication server 145, which may include the user’s device exchanging the ticket or key. In some examples, the authentication server 145 utilizes Kerberos to facilitate authentication. In some examples, the central server 105 or devices 115 may also employ Kerberos.

As mentioned above, aspects of the system 100 may be accessible by and managed through a web-based console 155. The console may include or be a user interface that provides access to maintain a directory, or portions of the directory, hosted on central server 105. As depicted in the example of FIG. 1, the console 155 may provide remote access to the central server 105 via an Internet connection and, for instance, a wireless access point 156. Those skilled in the art will recognize, however, that because central server 105 may be a cloud server, remote access to central server 105 may be achieved in a variety of ways. As discussed in further detail with reference to FIG. 3, the console 155 may allow an IT system administrator to manage user permissions, monitor access to various applications or files, and the like. The console 155 may be or employ a representational state transfer (REST) application programmer interface (API). The REST API may be used to search a directory, query the directory, or provision users for access to the directory via the console 155. Additionally or alternatively, the REST API may be used for authentication to the directory via the console 155.

The system 100 may, in some cases, include access by a device 160 hosting a server agent 165. The device 160 may be any type of computing device, including a server. Server agent 165 may be a software module (e.g., computer- or processor-executable code) that is configured to run certain software on device 160. The server agent 165 may be equipped with various submodules, including those for caching tasks or schedules, storing or registering user encryption certificates, or processing and executing commands. In some examples, the server agent 165 is capable of executing any number of commands or tasks. For instance, the server agent 165 may perform server functions related to user management, disk space management, log monitoring, changing system configurations, sending and receiving emails, or identifying and neutralizing security threats. The central server 105 may allow the server agent 165 to access a directory upon receiving a command via console 155. In some examples, credentials may be pushed from the central server 105 to the server agent 165. The server agent 165 may be preconfigured to authenticate a user as though the user was directly accessing, or attempting to access, the directory itself. In such cases, when a user authenticates to a device (e.g., console 155) where the server agent 165 is hosted, the server agent 165 may accomplish the authentication independently, providing user access to the directory.

In certain examples, system 100 also includes a remote authentication server 170 in communication with an device 115. The remote authentication server 170 may authenticate guest users of virtual private network (VPN) users for access to the directory reflected at the device 115. For instance,

remote authentication server **170** may provide access to a visiting user who connects to the system **100** via wireless access point **175**. Additionally or alternatively, remote authentication server **170** may authenticate users from customers described above who are off premises, and are accessing the central server **105** via VPN. In some examples, remote authentication server **170** employs Remote Authentication Dial In User Server (RADIUS), or some other protocol that supports authentication, authorization, and accounting. In some examples, the central server **105** or devices **115** may also employ RADIUS.

The various elements, components, servers and devices of system **100** may be connected to one another wirelessly or with wired connections. In some cases, they are connected via the Internet. Communication between the various devices may utilize Transport Layer Security (TLS), Secure Sockets Layer (SSL), or some other security or encryption protocol. As used herein, the term server refers to a computer or program in a network that provides services, including access to applications, files, peripherals, etc., to other computers or programs, or consoles within a network. As discussed below, this may include both software and hardware, and real and virtual machines. In some examples, a server is a computer program that operates to support or perform tasks on behalf of other programs, computers, or users. Further, as used herein, a server may include a "rack" or enclosure housing computer hardware and software.

The system **100** may thus support multitenant directory management. This may be accomplished, in part, with an integrated hosted directory on central server **105**, which may facilitate authentication, authorization, and management of IT resources across devices types, operating systems, and SaaS and on-premises applications.

FIG. 2 illustrates an example **200** of an integrated hosted directory **202** in a system, such as system **100** of FIG. 1, that supports multitenant directory management in accordance with various aspects of the present disclosure. The directory **202** may be stored in a directory server (or directory server module) **205** of a central server **105-a**, which may be an example of the central server **105** of FIG. 1. The directory **202** may be a system, such as a software system, that maps, organizes, and connects users to IT resources, including servers, devices, peripherals, applications, file systems, files, and the like. In some cases, the directory **202** may be referred to as a directory service. The directory **202** provides a system for allowing and maintaining records of which users are or should be allowed to access what IT resources, and whether, when, and by whom those IT resource were accessed.

The example of FIG. 2 illustrates one depiction of a directory **202**. The directory **202** may include fields or modules representative of users **210** and IT resources, such as file system **215**, devices **220**, files **230**, and instances **235**. The directory **202** may thus include a reference or references to IT resources. Additionally or alternatively, the directory may be said to reference IT resources. For example, the users **210** may be users associated with one or several customers. The directory **202** may provide a mapping to a file system **215** (or file systems) to which users **210** have access. The file system **215** may, in some cases represent applications, such as SaaS applications. The users **210** may also be mapped to certain devices **220**, which may be mapped to certain files **230** to which a user **210** or devices **220**, or both, has permissions. The devices **220** may be representative of devices **126** of FIG. 1. The files **230** may be mapped to instances **235**, which may provide details or information relevant to managing access by users **210**.

The directory **202** includes an arbitrary set of fields and modules for purposes of illustration. Those skilled in the art will recognize that a directory may take on a number of forms and may include fields different from those illustrated here.

FIG. 3 illustrates an example **300** of a web-based console **155-a** in a system, such as system **100** of FIG. 1, that supports multitenant directory management in accordance with various aspects of the present disclosure. The console **155-a** may include a user interface (UI) **305**, which may provide a portal for access to a directory, such as directory **202** of FIG. 2. The UI **305** may include fields **310**, icons, and the like that allow a user to interact with the directory **202**. The fields **310** may correspond or be associated with some or all of the IT resources (file system **215**, device **220**, files **230**, and instances **235**) of or referenced by the directory **202**. That is, a system administrator may, for example, navigate, identify, and manage the mapping of users to IT resources via the UI **305**.

The UI **305** may provide real-time information about user interactions with the directory via window **315**. For instance, the window **315** may display information about a particular user's permissions to access various IT resources. In some cases, the window **315** may also provide information about current and historic uses of such IT resources. Various devices, applications, security issues, and the like, related to a particular user may thus be monitored and managed via UI **305**.

FIG. 4 illustrates an exemplary process flow **400** in a system, such as system **100** of FIG. 1, that supports multitenant directory management in accordance with various aspects of the present disclosure. The process flow **400** may include a central server **105-b**, devices **115**, an authentication server **145-a**, on-premises server **125-c**, console **155-b**, SSO server **140-b**, a remote (e.g., server-agent hosting) device **160-a**, and users **405**. Each of these may examples of corresponding devices, entities, and the like, described with reference to FIGS. 1-3.

At **410**, a directory at a central server **105-b** may be accessed. The directory may be as described with reference to FIG. 2, and may include IT resources for a plurality of customers, such as customers having users **405**.

At **415**, a first device **115-e** may be activated and, at **420**, a first portion of the directory may be transmitted from the central server **105-b** to the first device **115-d**. The first portion of the directory may include IT resources for a first customer of the plurality of customers. At **425**, a second portion of the directory from the central server **105-b** to the first device **115-d**. The second portion of the directory may include IT resources for a second customer of the plurality of customers.

At **430**, a second device may be activated based, for instance, on a system load from the plurality of customers. For instance, the system load may exceed a threshold, as described above with reference to FIG. 1. At **435** the first portion of the directory may be transmitted from the central server **105-b** to the second device **115-e**, and at **440** the second portion of the directory may be transmitted from the central server **105-b** to the second device **115-e**.

At **445**, a first user **405** may be authenticated for access to the first portion of the directory at the first and second devices **115-d**, **115-e** utilizing a first protocol. The first user **405** may attempt to access a web-based application using a device, for example, and the directory may provide a mapping of that user's permission for such access. At **450**, a second use **405** may be authenticated for access to the

second portion of the directory at the first edge and second devices **115-d**, **115-e** utilizing the first protocol.

At **455**, a third user **405** may be authenticated for access to the first or second portion of the directory utilizing a second protocol that is different from the first protocol. This may include, at **460**, the third user **405** accessing a remote authentication server **145-a**, which may communicate with an device **115** or the central server **105** to facilitate authentication. In some examples, the first protocol is LDAP and the second protocol is Kerberos.

At **465**, the central server **105-b** may identify a command received via web-based console **155-b** and, at **470**, the central server **105-b** may receive a request for directory access from a server agent located on a remote device **160-a**. The central server **105-b** may, in response at **475**, transmit data to the server agent on remote device **160-a** in response to the request for directory access.

In some cases, at **480**, the first portion of the directory may be transmitted from the first device **115-d** to a portion of an on-premises server **125-c** of the first customer. As described above, the on-premises server **125-c** may include a replica module, which may be described as an LDAP sync replica or LDAP gateway, and which may be a copy of the first portion of the directory reflected at the on-premises server **125-c**.

At **485**, the central server **105-b** may be in communication with the SSO server **140-a** to support identity assertion to a third party on behalf of a customer of the plurality of customers. As described above, the identity assertion may be on the SSO server **140-b** accessing the directory on the central server **105-b**, and the SSO server **140-a** may utilize at least one of SAML, OpenID, or OAuth.

FIG. 5 illustrates an example **500** of a central server **105-c** that supports multitenant directory management in accordance with various aspects of the present disclosure. The central server **105-c** may be an example of central server **105** described with reference to FIGS. 1-4, and may include a directory server module **205-a**, a console server module **510**, and an agent server module **515**.

The directory server module **205-a** may be an example of the directory server module **205** of FIG. 2 and may host a directory **202** (FIG. 2). Some or all of the directory may be accessible to other components of the central server **105-b**. The directory server module **205-a** may, in some cases and in combination with other components of the central server **105-c**, access the directory, transmit portions of the directory, and authentication users for access to the directory, as described with reference to FIGS. 1 and 4.

The console server module **510** may, in combination with other components of the central server **105-c**, identify a command received via a web-based console, as described with reference to FIGS. 1 and 4. In some cases, the console server module **510** facilitates the operations described with reference to FIG. 3.

The agent server module **515** may cause the central server **105-c** receive a request for directory access from a server agent located on a remote device. In some cases, the agent server module **515**, in combination with other components of the central server **105-c**, may transmit data to the server agent in response to the request for directory access and based on the identified command, as described with reference to FIGS. 1 and 4.

The central server **105-c** may include a processor **520**, memory **525** (including software/firmware (SW) **530**), and a network communications module **535**. The various modules of the central server **105-c** may be in communication via one or more buses **540**. The network communications module

535 may be configured for secure, bi-directional communication with other devices, servers, and the like in a system, such as system **100** of FIG. 1, via one or more wired or wireless links. For example, the network communications module **535** may include a modem configured to modulate packets and transmit them to, and to demodulate received packets.

The memory **525** may include random access memory (RAM) and read only memory (ROM). The memory **525** may store computer-readable, computer-executable software/firmware code **530**, including instructions that, when executed, cause the processor **520** to perform various functions described herein (e.g., facilitating multitenant directory management.). Alternatively, the software/firmware code **530** may not be directly executable by the processor **520** but cause a computer (e.g., when compiled and executed) to perform functions described herein. The processor **520** may include an intelligent hardware device, (e.g., a central processing unit (CPU), a microcontroller, an ASIC, etc.).

FIG. 6 illustrates an example **600** of an device **115-f** that supports multitenant directory management in accordance with various aspects of the present disclosure. The device **115-f** may be an example of an device **115** described with reference to FIGS. 1-4, and may include a first customer directory module **605**, a second customer directory module **610**, and an nth customer directory module **615**.

The first customer directory module **605** and the second customer directory module **610** may receive, host, and provide authenticated access to first and second portions of a directory, respectively, from a central server **105**, as described with reference to FIGS. 1-5. The preceding description has generally discussed a first and second portion of the directory for first and second customers. Additional customers may be supported by the directory (e.g., **202** of FIG. 2). Thus, in some cases, an nth customer directory module may receive, host, and provide authenticated access to an nth portion of the directory from a central server **105**.

The device **115-f** may include a processor **620**, memory **625** (including software/firmware (SW) **630**), and a network communications module **635**. The various modules of the device **115-f** may be in communication via one or more buses **640**. The network communications module **635** may be configured for secure, bi-directional communication with other devices, servers, and the like in a system, such as system **100** of FIG. 1, via one or more wired or wireless links. For example, the network communications module **635** may include a modem configured to modulate packets and transmit them to, and to demodulate received packets.

The memory **625** may include random access memory (RAM) and read only memory (ROM). The memory **625** may store computer-readable, computer-executable software/firmware code **630**, including instructions that, when executed, cause the processor **620** to perform various functions described herein (e.g., facilitating multitenant directory management.). Alternatively, the software/firmware code **630** may not be directly executable by the processor **620** but cause a computer (e.g., when compiled and executed) to perform functions described herein. The processor **620** may include an intelligent hardware device, (e.g., a central processing unit (CPU), a microcontroller, an ASIC, etc.).

The components of central server **105-c** and device **115-f** may each, individually or collectively, be implemented with at least one ASIC adapted to perform some or all of the applicable functions in hardware. Alternatively, the functions may be performed by one or more other processing units (or cores), on at least one IC. In other examples, other

types of integrated circuits may be used (e.g., Structured/Platform ASICs, an FPGA, or another semi-custom IC), which may be programmed in any manner known in the art. The functions of each unit may also be implemented, in whole or in part, with instructions embodied in a memory, formatted to be executed by one or more general or application-specific processors.

FIG. 7 illustrates a method 700 for multitenant directory management in accordance with various aspects of the present disclosure. The operations of method 700 may be implemented by various servers and devices within a system, as described with reference to FIGS. 1-6. In some examples, one or more servers, such as central server 105, may execute a set of codes to control the functional elements of servers and devices with the system 100 to perform the functions described below. Additionally or alternatively, the central server 105 may perform aspects the functions described below using special-purpose hardware.

At block 705, the central server 105 may access a directory at the central server, where the directory comprises IT resources for a plurality of customers as described with reference to FIGS. 1-4. In certain examples, the operations of block 705 may be performed by the directory server module 205 as described with reference to FIGS. 2 and 5.

At block 710, the central server 105 may activate a first device of the plurality of devices as described with reference to FIGS. 1-4. In certain examples, the operations of block 710 may be performed by the directory server module 205 as described with reference to FIG. 5.

At block 715, the central server 105 may transmit a first portion of the directory from the central server to the first device, where the first portion of the directory includes IT resources for a first customer of the plurality of customers as described with reference to FIGS. 1-4. In certain examples, the operations of block 715 may be performed by the directory server module 205 or network communications module 535 as described with reference to FIG. 5.

At block 720, the central server 105 may transmit a second portion of the directory from the central server to the first device, where the second portion of the directory comprises IT resources for a second customer of the plurality of customers as described with reference to FIGS. 1-4. In certain examples, the operations of block 720 may be performed by the directory server module 205 or network communications module 535 as described with reference to FIG. 5.

At block 725, the central server 105 may activate a second device of the plurality of devices based at least in part on a system load from the plurality of customers as described with reference to FIGS. 1-4. In certain examples, the operations of block 725 may be performed by the directory server module 205 or network communications module 535 as described with reference to FIG. 5.

At block 730, the central server 105 may transmit the first and second portions of the directory to the second device as described in FIGS. 1-4. In certain examples, the operations of block 730 may be performed by the directory server module 205 or network communications module 535 as described with reference to FIG. 5.

At block 735, the central server 105 or one or more devices 115 may authenticate a first user for access to the first portion of the directory at the first and second devices utilizing a first protocol as described with reference to FIGS. 1-4. In certain examples, the operations of block 735 may be performed by the directory server module 205 as described with reference to FIG. 5.

FIG. 8 illustrates a method 800 for multitenant directory management in accordance with various aspects of the present disclosure. The operations of method 800 may be implemented by various servers and devices within a system, as described with reference to FIGS. 1-6. In some examples, one or more servers, such as central server 105, may execute a set of codes to control the functional elements of servers and devices with the system 100 to perform the functions described below. Additionally or alternatively, the central server 105 may perform aspects the functions described below using special-purpose hardware. The method 800 may also incorporate aspects of method 700 of FIG. 7.

At block 805, the central server 105 may access a directory at the central server, where the directory comprises IT resources for a plurality of customers as described with reference to FIGS. 1-4. In certain examples, the operations of block 805 may be performed by the directory server module 205 as described with reference to FIGS. 2 and 5.

At block 810, the central server 105 may activate a first device of the plurality of devices as described with reference to FIGS. 1-4. In certain examples, the operations of block 810 may be performed by the directory server module 205 as described with reference to FIG. 5.

At block 815, the central server 105 may transmit a first portion of the directory from the central server to the first device, where the first portion of the directory includes IT resources for a first customer of the plurality of customers as described with reference to FIGS. 1-4. In certain examples, the operations of block 815 may be performed by the directory server module 205 or network communications module 535 as described with reference to FIG. 5.

At block 820, the central server 105 may transmit a second portion of the directory from the central server to the first device, where the second portion of the directory comprises resources for a second customer of the plurality of customers as described with reference to FIGS. 1-4. In certain examples, the operations of block 820 may be performed by the directory server module 205 or network communications module 535 as described with reference to FIG. 5.

At block 825, the central server 105 may activate a second device of the plurality of devices based at least in part on a system load from the plurality of customers as described with reference to FIGS. 1-4. In certain examples, the operations of block 825 may be performed by the directory server module 205 or network communications module 535 as described with reference to FIG. 5.

At block 830, the central server 105 may transmit the first and second portions of the directory to the second device as described in FIGS. 1-4. In certain examples, the operations of block 830 may be performed by the directory server module 205 or network communications module 535 as described with reference to FIG. 5.

At block 835, the central server 105 or one or more devices 115 may authenticate a first user for access to the first portion of the directory at the first and second devices utilizing a first protocol as described with reference to FIGS. 1-4. In certain examples, the operations of block 835 may be performed by the directory server module 205 as described with reference to FIG. 5.

At block 840, the central server 105 may identify a command received via a web-based console as described with reference to FIGS. 1 and 4. In certain examples, the operations of block 840 may be performed by the console server module 510 as described with reference to FIG. 5.

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At block **845**, the central server **105** may receive a request for directory access from a server agent located on a remote device as describe with reference to FIGS. **1** and **4**. In certain examples, the operations of block **845** may be performed by the agent server module **515** as described with reference to FIG. **5**.

At block **850**, the central server **105** may transmit data to the server agent in response to the request for directory access based at least in part on the identified command as described with reference to FIGS. **1** and **4**. In certain examples, the operations of block **850** may be performed by the agent server module **515** as described with reference to FIG. **5**.

FIG. **9** illustrates a method **900** for multitenant directory management in accordance with various aspects of the present disclosure. The operations of method **900** may be implemented by various servers and devices within a system, as described with reference to FIGS. **1-6**. In some examples, one or more servers, such as central server **105**, may execute a set of codes to control the functional elements of servers and devices with the system **100** to perform the functions described below. Additionally or alternatively, the central server **105** may perform aspects the functions described below using special-purpose hardware. The method **800** may also incorporate aspects of methods **700** and **800** of FIGS. **7** and **8**.

At block **905**, the central server **105** may access a directory at the central server, where the directory comprises IT resources for a plurality of customers as described with reference to FIGS. **1-4**. In certain examples, the operations of block **905** may be performed by the directory server module **205** as described with reference to FIGS. **2** and **5**.

At block **910**, the central server **105** may activate a first device of the plurality of devices as described with reference to FIGS. **1-4**. In certain examples, the operations of block **910** may be performed by the directory server module **205** as described with reference to FIG. **5**.

At block **915**, the central server **105** may transmit a first portion of the directory from the central server to the first device, where the first portion of the directory includes IT resources for a first customer of the plurality of customers as described with reference to FIGS. **1-4**. In certain examples, the operations of block **915** may be performed by the directory server module **205** or network communications module **535** as described with reference to FIG. **5**.

At block **920**, the central server **105** may transmit a second portion of the directory from the central server to the first device, where the second portion of the directory comprises IT resources for a second customer of the plurality of customers as described with reference to FIGS. **1-4**. In certain examples, the operations of block **920** may be performed by the directory server module **205** or network communications module **535** as described with reference to FIG. **5**.

At block **925**, the central server **105** may activate a second device of the plurality of devices based at least in part on a system load from the plurality of customers as described with reference to FIGS. **1-4**. In certain examples, the operations of block **925** may be performed by the directory server module **205** or network communications module **535** as described with reference to FIG. **5**.

At block **930**, the central server **105** may transmit the first and second portions of the directory to the second device as described in FIGS. **1-4**. In certain examples, the operations of block **930** may be performed by the directory server module **205** or network communications module **535** as described with reference to FIG. **5**.

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At block **935**, the central server **105** or one or more devices **115** may authenticate a first user for access to the first portion of the directory at the first and second devices utilizing a first protocol as described with reference to FIGS. **1-4**. In certain examples, the operations of block **935** may be performed by the directory server module **205** as described with reference to FIG. **5**.

At block **940**, the central server **105** may authenticate a second user for access to the second portion of the directory at the first edge and second devices utilizing the first protocol as described with reference to FIGS. **1-4**. In certain examples, the operations of block **940** may be performed by the directory server module **205** as described with reference to FIG. **5**.

At block **945**, the central server **105** or the authentication server **145**, or both, may authenticate a third user for access to the first or second portion of the directory utilizing a second protocol that is different from the first protocol as described with reference to FIGS. **1** and **4**. In certain examples, the operations of block **945** may be performed by the directory server module **205** as described with reference to FIG. **5**.

At block **950**, the central server **105** may communicate with an authentication server that supports authentication using the second protocol, where the third user may be authenticated via a request to the authentication server as described with reference to FIGS. **1** and **4**. In certain examples, the operations of block **950** may be performed by the network communications module **535** as described with reference to FIG. **5**.

FIG. **10** illustrates a method **1000** for multitenant directory management in accordance with various aspects of the present disclosure. The operations of method **1000** may be implemented by various servers and devices within a system, as described with reference to FIGS. **1-6**. In some examples, one or more servers, such as central server **105**, may execute a set of codes to control the functional elements of servers and devices with the system **100** to perform the functions described below. Additionally or alternatively, the central server **105** may perform aspects the functions described below using special-purpose hardware. The method **800** may also incorporate aspects of methods **700**, **800**, and **900** of FIGS. **7**, **8**, and **9**.

At block **1005**, the central server **105** may access a directory at the central server, where the directory comprises IT resources for a plurality of customers as described with reference to FIGS. **1-4**. In certain examples, the operations of block **1005** may be performed by the directory server module **205** as described with reference to FIGS. **2** and **5**.

At block **1010**, the central server **105** may activate a first device of the plurality of devices as described with reference to FIGS. **1-4**. In certain examples, the operations of block **1010** may be performed by the directory server module **205** as described with reference to FIG. **5**.

At block **1015**, the central server **105** may transmit a first portion of the directory from the central server to the first device, where the first portion of the directory includes IT resources for a first customer of the plurality of customers as described with reference to FIGS. **1-4**. In certain examples, the operations of block **1015** may be performed by the directory server module **205** or network communications module **535** as described with reference to FIG. **5**.

At block **1020**, the central server **105** may transmit a second portion of the directory from the central server to the first device, where the second portion of the directory comprises IT resources for a second customer of the plurality of customers as described with reference to FIGS. **1-4**, In

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certain examples, the operations of block 1020 may be performed by the directory server module 205 or network communications module 535 as described with reference to FIG. 5.

At block 1025, the central server 105 may activate a second device of the plurality of devices based at least in part on a system load from the plurality of customers as described with reference to FIGS. 1-4. In certain examples, the operations of block 1025 may be performed by the directory server module 205 or network communications module 535 as described with reference to FIG. 5.

At block 1030, the central server 105 may transmit the first and second portions of the directory to the second device as described in FIGS. 1-4. In certain examples, the operations of block 1030 may be performed by the directory server module 205 or network communications module 535 as described with reference to FIG. 5.

At block 1035, the central server 105 or one or more devices 115 may authenticate a first user for access to the first portion of the directory at the first and second devices utilizing a first protocol as described with reference to FIGS. 1-4. In certain examples, the operations of block 1035 may be performed by the directory server module 205 as described with reference to FIG. 5.

At block 1040, the central server 105 and one or more devices 115 may transmit the first portion of the directory from the first device to a portion of an on-premises server of the first customer as described in FIGS. 1 and 4. In certain examples, the operations of block 1040 may be performed by the directory server module 205 and the network communications module 535 as described with reference to FIG. 5, or the first customer directory module 605 and the network communications module 635 as describe with reference to FIG. 6.

At block 1045, the central server 105 may communicate with a single-sign-on server to support identity assertion to a third party on behalf of a customer of the plurality of customers as described with reference to FIGS. 1 and 4. The identity assertion may be based at least in part on the single-sign-on server accessing the directory. In certain examples, the operations of block 1040 may be performed by the directory server module 205 and the network communications module 535 as described with reference to FIG. 5.

Thus, methods 700, 800, 900 and 1000 may provide for multitenant directory management, which may utilize an integrated hosted directory. It should be noted that methods 700, 800, 900 and 1000 describe possible implementations, and that the operations and the steps may be rearranged or otherwise modified such that other implementations are possible. In some examples, aspects from two or more of the methods 700, 800, 900 and 1000 may be combined.

The description herein provides examples, and is not limiting of the scope, applicability, or examples set forth in the claims. Changes may be made in the function and arrangement of elements discussed without departing from the scope of the disclosure. Various examples may omit, substitute, or add various procedures or components as appropriate. Also, features described with respect to some examples may be combined in other examples.

The description set forth herein, in connection with the appended drawings, describes example configurations and does not represent all the examples that may be implemented or that are within the scope of the claims. The term "exemplary" as may be used herein means "serving as an example, instance, or illustration," and not "preferred" or "advantageous over other examples." The detailed description

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includes specific details for the purpose of providing an understanding of the described techniques. These techniques, however, may be practiced without these specific details. In some instances, well-known structures and devices are shown in block diagram form in order to avoid obscuring the concepts of the described examples.

In the appended figures, similar components or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If just the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label.

Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

The various illustrative blocks and modules described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a digital signal processor (DSP) and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration).

The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described above can be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations. Also, as used herein, including in the claims, "or" as used in a list of items (for example, a list of items prefaced by a phrase such as "at least one of" or "one or more of") indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C).

Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that can be accessed by a general purpose or special purpose computer. By way of example, and not limitation, non-transitory computer-readable media can comprise RAM, ROM, electrically erasable programmable read only memory (EEPROM), compact

disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that can be used to carry or store desired program code means in the form of instructions or data structures and that can be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include CD, laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of computer-readable media.

The description herein is provided to enable a person skilled in the art to make or use the disclosure. Various modifications to the disclosure will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not to be limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

1. A method, comprising:

receiving, from a device that manages a directory that comprises a mapping between a plurality of users and a plurality of information technology (IT) resources, at least a subset of a first portion of the directory, wherein: the first portion of the directory comprises references to a first set of IT resources of the plurality of IT resources associated with a first organization, wherein the first organization comprises a first set of users of the plurality of users, and

a second portion of the directory comprises references to a second set of IT resources of the plurality of IT resources associated with a second organization, the second organization comprising a second set of users of the plurality of users;

authenticating, using the subset of the first portion of the directory, a user of the first organization for access to an IT resource of the first set of IT resources, wherein the subset of the first portion of the directory comprises references to the IT resource that comprise a permission for the user of the first organization to access the IT resource, and wherein the authenticating is based at least in part on an attempt of the user of the first organization to access a functionality of the IT resource; and

providing, to the IT resource based at least in part on authenticating the user of the first organization, an indication that the user of the first organization is assigned the permission.

2. The method of claim 1, further comprising:

providing, to a second device being used by the user of a first organization and based at least in part on authenticating the user of the first organization, a second indication that the user of the first organization is assigned the permission to access the functionality of the IT resource.

3. The method of claim 1, wherein the IT resource includes file systems.

4. The method of claim 1, further comprising:

receiving a request to authenticate the user of the first organization for access to the IT resource, wherein the user of the first organization is authenticated for access to the IT resource based at least in part on the request.

5. The method of claim 1, wherein the user of the first organization is authenticated for access to the IT resource using a first protocol, the method further comprising:

authenticating, using a subset of the second portion of the directory received from the device that manages the directory, a user of the second organization for access to an IT resource of the second set of IT resources using a second protocol, wherein the authenticating is based at least in part on an attempt of the user of the second organization to access a functionality of the IT resource of the second set of IT resources.

6. The method of claim 1, wherein:

the subset of the first portion of the directory is received at a second device, and

the second device comprises an on-premises server of the first organization, an authentication server, an edge server, or any combination thereof.

7. The method of claim 1, wherein the subset of the first portion of the directory is received at an agent of a second device being used by the user of the first organization.

8. The method of claim 1, wherein receiving the subset of the first portion of the directory comprises:

receiving the first portion of the directory and the second portion of the directory from the device.

9. The method of claim 8, further comprising:

transmitting the first portion of the directory and the second portion of the directory to a second device based at least in part on a resource utilization exceeding a threshold.

10. The method of claim 1, further comprising:

deauthenticating the user of the first organization for access to the IT resource based at least in part on the permission being revoked due to an occurrence of one or more events within a threshold time, the one or more events comprising receiving requests on behalf of the user of the first organization to access the first portion of the directory multiple times, from multiple IP addresses, or both.

11. The method of claim 1, wherein:

the plurality of IT resources comprise a computing device, an application, a file system, files, or any combination thereof, and

one or more IT resources of the plurality of IT resources are included in the first set of IT resources and the second set of IT resources.

12. A method, comprising:

receiving, from a first device that manages a directory that comprises a mapping between a plurality of devices and a plurality of information technology (IT) resources, at least a subset of a first portion of the directory, wherein:

the first portion of the directory comprises references to a first set of IT resources of the plurality of IT resources for a first organization, wherein the first organization comprises a first set of devices of the plurality of devices, and

a second portion of the directory comprises references to a second set of IT resources of the plurality of IT

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resources for a second organization, the second organization comprising a second set of devices of the plurality of devices;

authenticating, using the subset of the first portion of the directory, a device of the first organization for access to an IT resource of the first set of IT resources, wherein the subset of the first portion of the directory comprises references to the IT resource that comprise a permission for the device of the first organization to access the IT resource, and wherein the authenticating is based at least in part on an attempt of the device of the first organization to access a functionality of the IT resource; and

providing, based at least in part on authenticating the device of the first organization, an indication to the IT resource that the device of the first organization is assigned the permission.

13. The method of claim 12, further comprising: providing, to the device of the first organization based at least in part on authenticating the device of the first organization, a second indication that the device of the first organization is assigned the permission to access the functionality of the IT resource.

14. The method of claim 12, wherein the IT resource includes file systems.

15. The method of claim 12, wherein: the subset of the first portion of the directory is received at a second device, the second device comprises an on-premises server of the first organization, an authentication server, an edge server, or any combination thereof, or the second device is the device of the first organization.

16. A system, comprising: a first hardware-implemented device comprising a directory that comprises a mapping between a plurality of users and a plurality of information technology (IT) resources, a plurality of devices and the plurality of IT resources, or both, wherein:

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a first portion of the directory comprises references to a first set of IT resources of the plurality of IT resources for a first organization, wherein the first organization comprises a first set of users of the plurality of users, a first set of devices of the plurality of devices, or both, and

a second portion of the directory comprises references to a second set of IT resources of the plurality of IT resources for a second organization, the second organization comprising a second set of users of the plurality of users, a second set of devices of the plurality of devices, or both; and

a second hardware-implemented device that is configured to:

receive, from the first hardware-implemented device, at least a subset of the first portion of the directory that comprises references to an IT resource of the first set of IT resources, the references to the IT resource comprising a first permission for a user of the first organization to access the IT resource, a second permission for a device of the first organization to access the IT resource, or both,

authenticate, using the subset of the first portion of the directory, the user of the first organization or the device of the first organization for access to the IT resource, wherein the authenticating is based at least in part on an attempt of the user of the first organization or the device of the first organization to access a functionality of the IT resource, and

provide, to the IT resource based at least in part on authenticating the user of the first organization or the device of the first organization, an indication that the user of the first organization is assigned the first permission, the device of the first organization is assigned the second permission, or both.

17. The system of claim 16, wherein the IT resource includes file systems.

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